

FERROELECTRIC MEMORY CELL  
AND CORRESPONDING MANUFACTURING METHOD

CROSS-REFERENCE TO RELATED APPLICATION

This application is a divisional of U.S. Patent Application No. 09/610,311,  
5 filed July 5, 2000, now pending, which application is incorporated herein by reference in  
its entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to a ferroelectric memory cell, and a method for its  
10 manufacture.

Description of the Related Art

Electronic memory devices that include ferroelectric components integrated  
on a semiconductor can include a number of ferroelectric memory cells organized in a  
matrix form of rows and columns, coupled by word and bit lines, respectively.

15 Each ferroelectric memory cell has a MOS transistor and a ferroelectric  
capacitor.

Known processes for manufacturing such memory cells include, after the  
MOS transistor is integrated in a semiconductor substrate, covering the entire chip surface  
with an insulating layer.

20 The ferroelectric capacitor is formed on top of this insulating layer. The  
capacitor conventionally includes a lower electrode of metal placed onto the insulating  
layer. A ferroelectric material layer covers the lower electrode, and a metal upper electrode  
is laid onto the ferroelectric layer.

An electrode of the ferroelectric capacitor is then connected to a conduction  
25 electrode of the MOS transistor.

After forming the ferroelectric memory cell, the next metallization layers are formed as necessary to complete the memory circuit structure.

This solution has a number of drawbacks. The required treatment for the provision of metallization levels can damage the properties of the ferroelectric materials, and with it, the performance of a ferroelectric memory cell.

A prior approach to attenuating this problem is described by Amanuma in an article "Capacitor-on-Metal/Via-stacked-Plug (CMVP) Memory Cell for 0.25 $\mu$ m CMOS Embedded FeRAM", published in March, 1998 by IEEE and incorporated herein by this reference in toto.

The article describes a ferroelectric memory cell comprising a MOS transistor integrated in a semiconductor, the formation of two metallization levels followed by the formation of a ferroelectric capacitor, and ultimately the formation of a final metallization layer.

Although achieving its objective, not even this solution is devoid of drawbacks. The provision of a final metallization layer after forming the ferroelectric capacitor results, in fact, in degradation of the ferroelectric material.

Until now, no memory device or process for making a memory device was available to provide a ferroelectric memory cell with such construction and functional features as to retain the ferroelectric characteristics of its component materials and overcome the limitations and drawbacks that still beset prior art ferroelectric memory devices.

## BRIEF SUMMARY OF THE INVENTION

Embodiments of the invention provide a memory structure which has at least one ferroelectric memory cell consisting of a MOS transistor connected to a ferroelectric capacitor, wherein the ferroelectric capacitor is formed after all the metallization levels of the memory structure have been formed.

Presented is a memory cell integrated in a semiconductor substrate that has a MOS device with an overlying metallization layer. An insulating layer covers the

metallization layer. Over the insulating layer is formed a capacitive element having a lower electrode covered with a layer of a dielectric material and capacitively coupled to an upper electrode. The metallization layer extends only between the MOS device and the lower electrode of the capacitive element. Also presented is a method to make the cell just  
5 described.

The invention relates, particularly but not exclusively, to a non-volatile ferroelectric memory cell, and the description to follow deals with this field of application for simplicity.

#### BRIEF DESCRIPTION OF THE DRAWINGS

10 Figure 1 is an layout view showing a portion of a memory matrix which has ferroelectric memory cells according to embodiments invention.

Figure 2 is a sectional view of Figure 1 taken along line II-II.

Figure 3 is a sectional view of Figure 1 taken along line III-III.

Figure 4 is a sectional view, similar to Figure 2, of another embodiment of  
15 the invention.

Figure 5 is a sectional view of Figure 1 taken along line III-III, also showing an external contact area for the memory matrix according to an embodiment of the invention.

Figure 6 is a sectional view of Figure 1 taken along line III-III, also showing  
20 another embodiment of the external contact for the memory matrix.

#### DETAILED DESCRIPTION OF THE INVENTION

Referring to the drawing views, a ferroelectric memory cell according to an embodiment of the invention will now be described.

Figure 1 shows a portion of a memory matrix 1 including a number of non-  
25 volatile ferroelectric memory cells 2, integrated on a semiconductor substrate 3. These cells 2 are laid into rows and columns, and are accessed through wordlines WL and bitlines BL. Each of the memory cells lies at a junction of one wordline WL and one bitline BL.

Figures 2 and 4 show a cross-sectional view of the ferroelectric memory cells 2. Each ferroelectric memory cell 2 includes a MOS transistor 4 coupled to a capacitive element 5.

Each MOS transistor 4 has first and second conduction terminals 6, which are formed in respective source and drain regions of the substrate 3.

A gate (or control) electrode 7 of polysilicon overlies the substrate region 3 between pairs of conduction terminals 6, and is isolated from the substrate surface by a thin oxide layer.

The gate electrodes 7 of transistors 4 in the same row are generally formed from polysilicon and coupled to a single word line WL, also generally formed from polysilicon. Each word line electrically interconnects the transistors 4 in the same row of the matrix 1.

In this configuration, adjacent pairs of transistors 4 in the same column BL have a conduction terminal 6 in common.

A protective insulating layer 8, such as an oxide doped with boron and phosphorus (BPSG), is then formed over the entire semiconductor surface. Respective openings are conventionally provided through the protective insulating layer 8 aligned with the conduction terminals 6, to form respective contacts 9.

Advantageously at this step, all the metallization levels that are necessary to complete the circuit structure in which the memory device 1 is integrated, are formed.

After the contact opening through the insulating layer 8 is formed, a first metallization layer 10 is formed conventionally, which is then patterned to provide specified electric interconnections.

In particular, a number of pads 10a are formed at the contacts 9 connected to the source terminal of the transistor 4, and a plurality of pads 10b are formed at the drain of the transistor 4 for connection to a respective bit line BL.

A second protective insulating layer 11 is subsequently formed to cover the semiconductor surface. Respective openings are provided through the insulating layer 11 aligned with the pads 10a for conventionally producing respective contacts 12.

A second metallization layer 13 is formed and then patterned to provide specified electric interconnections. In particular, a number of pads 13a are formed aligned with the contacts 12 that are connected to the source terminal of the transistor 4.

In a specially advantageous embodiment shown in Figure 4, auxiliary word lines WL1 are formed from this metallization layer 13.

These word lines WL1 are placed in contact, outside the matrix 1, with the word lines WL which connect the gate electrodes 7 of the transistors 4.

In this way, the resistance of the polysilicon word lines WL can be made lower than only using the wordlines WL themselves, thereby making for faster response of the cells 2.

A third protective insulating layer 14 is subsequently formed over the semiconductor surface.

Respective openings are provided through the insulating layer 14 aligned with the pads 13a to enable the formation of respective contacts 15.

Ferroelectric capacitors 5 are then provided at each MOS transistor 4. Each ferroelectric capacitor 5 has a lower electrode 16 made of metal, *e.g.*, of platinum, placed on the insulating layer 14 at the location of a respective contact 15.

In this particular embodiment, the lower electrode 16 advantageously overlaps the control electrode 7, at least partially.

A layer 17 of a ferroelectric material covers the lower electrode 16. Preferably, the ferroelectric material layer 12 covers the entire area occupied by the memory cells.

An upper electrode 18 of metal, *e.g.*, of platinum, is then formed on the ferroelectric material layer 17. This upper electrode 18 is so defined as to overlap each lower electrode 16, at least partially.

Advantageously, the upper electrodes 18 of cells 2 in the same matrix row are connected into a single line PL designated "plate line", as shown in Figure 1.

A passivation layer 19 is formed that covers the semiconductor surface.

All of the metallization levels 10, 13 are included between the MOS device and the lower electrode 16 of the capacitive element 5. In other words, no metallization levels are provided above the electrodes 16, 18 of the capacitor 5.

As shown in Figure 3, an end termination 20 can be provided, outside the area of the memory matrix 1, which includes a pad 13b formed from the second metallization layer 13.

This pad 13b is overlaid by an associated contact 15a which is surrounded by the oxide layer 14. A flat 16a is formed, at the contact 15a, from the platinum layer from which the first plates 16 of the capacitor 5 were formed.

This flat 16a is then covered with the plate line PL interconnecting the upper plates 18 of the capacitors 5 in the same row of the matrix 1.

This solution allows the outputs from the memory cells (upper electrodes 18) to be driven and decoded through a metallization level provided beneath the ferroelectric capacitor 5.

Shown in Figure 5 is a first embodiment of a possible area of connection to the output of the circuit. In this first embodiment, a pad area 21 is formed from the second metallization level 13, outside the matrix 1.

After the capacitors 5 are formed in the matrix 1 as previously described, the top insulating layer 14 and the passivation layer 19 are removed from a portion of the pad area 21 to provide for the connections to the output.

Another possible embodiment of this pad area is illustrated in Figure 6. In particular, after forming the protective insulating layer 14, a pad area 21a is provided outside the matrix area by the formation of a further metallization layer. Once this pad area 21a is formed, the capacitors 5 are formed as previously described.

The passivation layer 19 deposited over the entire semiconductor surface is then removed to produce the connections to the output.

In summary, the memory cell 1 enables the ferroelectric device to be fabricated after the last metallization layer has been formed. Thus, the problems involved

in integrating the ferroelectric devices with standard CMOS fabrication processes have been reduced substantially.

Changes can be made to the invention in light of the above detailed description. In general, in the following claims, the terms used should not be construed to  
5 limit the invention to the specific embodiments disclosed in the specification and the claims, but should be construed to include all methods and devices that are in accordance with the claims. Accordingly, the invention is not limited by the disclosure, but instead its scope is to be determined by the following claims: